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Energy Procedia 1 (2009) 4727–4733

Energy Procedia

www.elsevier.com/locate/procedia

GHGT-9

Improving the global carbon capture and storage educational capacity

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Abstract

Carbon capture and storage (CCS) is commonly regarded as a key element in the mitigation of climate change. CCS is of particular interest as it is able to address emissions from fossil fuel power stations, reducing CO_2 emissions by 80-90%, without a step change in technology or lifestyle within a country. This is of particular relevance for the large and growing coal fired power plant capacity in the developing world, particularly China and India.

If CCS is going to make a significant impact on global CO_2 emissions then the development and deployment of the technology over the next 50 to 100 years will have to be significant. Currently however, the global awareness and educational levels around CCS technology is low and mainly confined to the developed world. To meet the requirements of the future CCS industry this educational capacity must be increased.

There are a number of key areas relating to the improvement of educational capacity.

- Information dissemination
- Undergraduate studies
- Post-graduate research
- Professional training program

The scope of this paper only includes the undergraduate and post-graduate areas. Post-graduate work in CCS is currently the best developed of the four areas of educational capacity. However the bulk of quality post-graduate research would still only emanate from a small number of universities in developed countries. Undergraduate studies in CCS are currently non-existent. The only inclusion of CCS in undergraduate program currently is the mention of the general principles briefly as part of a much broader engineering program.

This paper will look at international efforts to address the need to develop educational capacity in CCS. This will include looking at current training programs that exist such as the European CO2ReMoVe Course on CCS, the US-Norway Summer School for CCS, Research Experience in Carbon Sequestration (RECS), and the IEA GHG International Summer School on CCS. All the current programs are aimed at post-graduate students who are currently conducting research in a CCS relevant field and mainly focus on the developed world. The paper will

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doi:10.1016/j.egypro.2009.02.297

discuss the history and outcomes of such programs to make some assessment of the impact these programs have had in the CCS industry.

The paper will then go on to look at ways in which these could be expanded and developed in the future including how current educational programs could be extended or modified to address CCS education amongst undergraduate students. An assessment will also be made on how these programs could be transferred and initiated in the developing world. Finally the paper will go on to propose some new ways to improve CCS educational capacity for students around the world.

Key Words: CO_2 capture and storage; Educational capacity; Summer school

1. Introduction

CO_2 capture and storage (CCS) is commonly regarded as a key option for the mitigation of climate change. CCS is not the only mitigation option, all options including nuclear power, renewable energy, energy efficiency etc, will need to be utilized to achieve substantial reductions in global greenhouse gas emissions. However, CCS is of particular interest as it is able to address emissions from fossil fuel power stations, reducing CO_2 emissions by 80 - 90%, without a step change in technology or lifestyle within a country. This is of particular relevance for the large and growing coal fired power plant capacity in the developing world, particularly China and India.

If CCS is going to make a significant impact on global CO_2 emissions then the development and deployment of the technology over the next 50 to 100 years will have to be significant. Currently however, the global awareness and educational levels around CCS technology is low and mainly confined to the developed world. To meet the requirements of the future CCS industry this educational capacity must be increased.

2. Questionnaire

To help with the review of the current educational capacity of CCS, a small survey was conducted amongst students studying CCS. The aim of the questionnaire was to assess when and how the students were introduced to the concept of CCS, how much interaction they have with other CCS students and the CCS industry, and to see what direction they want to take their CCS studies in the future. The survey was circulated to two-hundred students. Of those two-hundred plus students who were sent the survey, a total of fifty-six responses were received. Within the fifty-six responses there were students from forty-one universities in twenty-seven countries with the students themselves from twenty countries of origin. The students were evenly spread between developed and developing countries (54% developed, 46% developing). The ages of the students who responded ranged between twenty-one and forty-three with an average age of twenty-eight. In the group of fifty-five responses, there were;

- 30 PhD students
- 20 Masters students
- 3 Post-doctoral students
- 1 Post-master student
- 1 Internship student

The students polled came from the IEA GHG student database. The student database was compiled from all those who applied to attend the IEA GHG Summer School programmes in 2007 and 2008. It is acknowledged that the sample size and method of identification does mean that the results may not be representative however it is felt that the sample size is large enough and from a diverse enough background to draw some general conclusions about the state of the industry. The hope is that this preliminary review may lead to further more detailed study in the future.

Question 1 - When and how did you first learn about the concept of CO_2 capture and storage (CCS)? Most of the sample was introduced to the concept of CCS during their post-graduate studies (62%). This was followed by

professional activities (14%), undergraduate studies (13%), and the media (11%). Of the students sampled, none were introduced to the concept of CCS during high school. Awareness about CCS will be critical to both increasing the number of students in the field and to gaining the support of government and the public. It is not a very good indication of the awareness of CCS to see that educated students who are doing their undergraduate studies in fields related to CCS are not being introduced to the concept.

Question 2 - Prior to your current studies, did you ever encounter CCS with in a formal curriculum? 77% of the students had not had any introduction to CCS within formal studies prior to their current post-graduate studies and of the 23% who had encountered CCS prior to their current studies, most indicated that it was during previous post-graduate studies. This then shows that although *question* 1 indicated that 13% of students were introduced to the concept of CCS during their undergraduate studies, only 7% had it feature formally in the curriculum. This would indicate that students who are graduating and taking on research and postgraduate studies in CCS are not doing so for any desire to work in the CCS industry but are rather responding to research opportunities that are being presented to them. This would imply that current postgraduate courses are primarily reliant on a select number of dedicated staff who themselves are interested in CCS who then pick up the students as they graduate and introduce them to the concept of CCS. Although this works on a small scale a more formal recruitment process will be required to meet the demands on the CCS industry in the future.

Question 3 - When you first studied CCS, in what part of the curriculum did it feature? The responses received from question 3 were categorised for the purposes of analysis. From a reduced sample [†], engineering was the dominant part of the curriculum (47%) followed by; environmental science (19%), chemistry (15%), geology (12%), and politics (7%). This result gives an indication of the key subject areas that should be addressed at an undergraduate level to increase the intake of students at a postgraduate level.

Question 4 - Does your professor/supervisor work specifically on CCS? From a reduced sample [‡], 65% of supervisors work specifically on CCS with the remaining 35% only working on CCS part of their time or not at all. This result supports the suggestion that current CCS postgraduate courses are being sustained by dedicated professors who focus on the area of CCS.

Question 5 - How many other students are working of CCS in your department and university? In total two hundred and eighty-four students were identified to be working in CCS across the 41 universities represented. It is clear that this number only represents the opinions of those students surveyed which could potentially vary greatly from the actual number working in CCS within the university however there are some interesting trends in the results. The response gives an average number of students per university to be 6.9 however looking at the result in more detail there is a significant step down from the six universities with the largest number of students and the rest of the sampled universities. The top six (15% of universities represented) make up 66% of the identified students with an average of 31.2 students in each of these universities. The remaining thirty-five universities have an average of only 2.8 students per university.

Question 6 - What interaction do you have with other students studying CCS; within your University, at other Universities, Internationally? 32% of the sample have no interaction at all with other students studying CCS, interestingly a further 32% of the sample have had interacted internationally with other CCS students. Of the remaining students, 16% interact within their department, 9% within their university and 11% nationally. Looking at the comparison here between developed and developing countries give very interesting results. 64% of the developing countries responses said they have no interaction with any other CCS students whereas in developed countries this figure is reduced to 21%.

Question 7 - What interaction do you have with the CCS industry? 27% of the sample indicated they have no interaction with industry. 36% interact with industry at conferences, 21% have their studies funded by industry, 16%

[†] *Of the fifty-six responses received, eight could not be categorized due to lack of information in their response so for the analysis of this question a sample size of just forty-eight is used.*

[‡] *One student did not identify if their supervisor worked specifically on CCS so for the analysis of this question a sample size of just fifty-five is used.*

engage in joint research with industry.. It is very interesting to note that in general students have more interaction with industry than they have with other students in the field of CCS. Perhaps this finding is because CCS is currently a niche industry with the small number of students involved able to attain the funding and support more readily than if there were more students in the field. Like *Question 6*, developing countries had much less interaction with industry. 36% of students in developing countries have no interaction with industry whereas 24% of students in developed countries have no interaction with industry. Of the developing country students, only 7% have direct contact with industry through sponsorship or joint research where as 48% of developed country students have this interaction.

Question 8 - Have you attended any specific CCS courses? 71% of the sample had not attended any specific CCS courses leaving only 29% who had. This however is the question most susceptible to the sample selection method with 16% of the sample having attended the IEA GHG Summer School in 2007. With this section of the sample removed, only 15% of the remaining sample had attended a course on CCS with the remaining 85% having not attended a course. Although there are a number of organisations who are looking to run courses on CCS, there is still a limited number of students who have been able to attend. Courses give the students a unique opportunity to interact with students and experts in a more informal way enabling a more "two-way" interaction than at other events such as conferences. This is particularly useful in enabling students to build a network of contacts who could assist them in their studies and career in the future.

Question 9 - Are you looking to pursue a career in CCS? If so would this be in Industry, Academia, Government, other? Do you have anything arranged? 80% of the sample are looking to pursue a career in CCS after graduating from their current studies with only 2% (1 response) not looking to pursue a career in CCS. The other 18% stated that they were currently undecided. When asked about the type of career they wish to pursue after graduation, only 59% of the sample provided a response. The fact that 41% of the total sample did not give a response to the question would indicate that they are undecided about the type of career they wish to pursue after graduation. In respect to the reduced sample [§] that did provide an answer to this part of the question, 37% of signalled an interest in moving into private industry follow graduation, 27% said academia, 18% government and 3% (1 response) indicated that they intend to work for an environmental NGO. In addition to this, 12% of the sample indicated both industry and academia as potential options, and 3% (1 response) indicated industry and government. It is interesting to note that 48% [**] of the reduced sample would prefer not to go into private industry following their studies. As it is most likely to be the private industry that will be responsible for building and operating CCS plants in the future, a greater percentage of CCS trained graduates will have to move into private industry in the future. This breakdown may however be a reflection of the current status of the CCS industry which is currently focused on researching, developing and proving technology and regulation rather than developing CCS plants at a commercial scale. For the final part of the question, 86% of the sample indicated that they have not yet arranged any employment for when they finish their studies, 12% have arranged employment, and 2% (1 response) did not answer.

3. Current Activities

In an attempt to address the educational capacity for CCS around the world a number of programmes are being ran for students studying CCS. These programmes range from one day courses, commercial seminars, to fully funded summer schools. To demonstrate the types of programmes being ran, a number of examples are presented below. The list presented does not represent all programmes that exist but are rather examples of what is being done.

IEA GHG International CCS Summer School

The IEA GHG International CCS Summer School was launched in 2007 with the first school being held in Germany and was followed up this year with the second summer school in Canada. The IEA GHG summer school is an initiative of the IEA GHG Programme and is funded by programme members and local sponsors. Between fifty and sixty students attend the school which includes five days of lectures, group work and networking time. The scope of

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[§] *Of the fifty-six responses received, twenty-three did not provide an answer to the question so for the analysis of this question a sample size of just thirty-four is used.*

[**] *For the purposes of this comparison, students who selected industry and a second choice were counted in the industry figure.*

the summer school covers a wide range of technical and non-technical aspects of CCS from capture, storage, and transport technologies, to finance, legal and public acceptance. The students are all post-graduate students who have experience in CCS. Students are recommended to the IEA GHG programme from their membership and the school is also announced in the IEA GHG Greenhouse Gas Issues newsletter. Students are then selected to attend the school based on academic background and supervisor endorsement. Students are also selected to get a well balanced international cohort. To date one hundred and fifteen students have attended the school from thirty-three countries representing all six continents (*See Figure 1*). The lecture programme and group work is led by international CCS experts who also stay at the venue for the duration of the school to allow maximum exposure to the students. The 2009 IEA GHG Summer School will be held in Australia with the 2010 school in Norway.

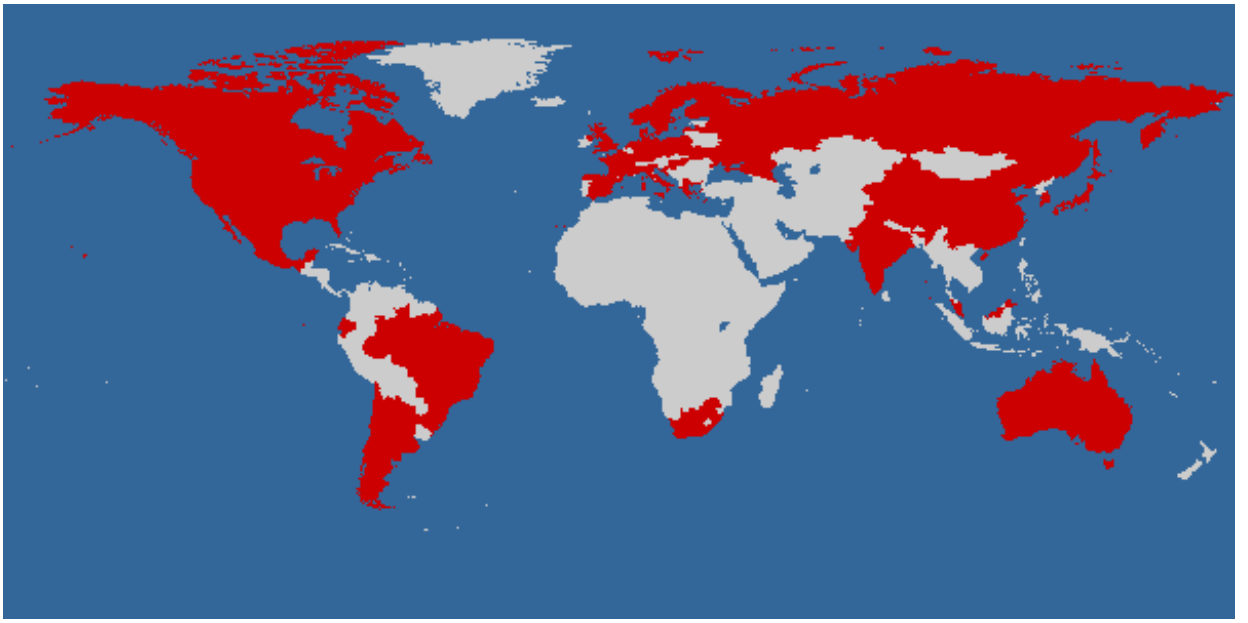

Figure 1: Countries represented in the IEA GHG CCS Summer School Programme

Research Experience in Carbon Sequestration (RECS)

The RECS summer school was launched in 2004 and has been held each year since, in the USA. The RECS summer school is organised by EnTech Strategies, LLC with technical collaboration from national laboratories and CCS research consortia. It is primarily funded by the US Department of Energy along with a number of industry sponsors. Around twenty-five students attend the school which runs for ten days. The RECS summer school programme covers a host of technical and non-technical issues relating to CCS and involves lectures and group work as well as CCS related field visits. In 2008 the field visit included a trip to a coal fired power station, a CO_2 injection site, and to the Mesa Verde National Park. The school is open to early career professionals, post-graduate students and exceptional undergraduate students with a background in geology, chemistry, hydrology or physics, reservoir, mechanical or chemical engineering, CCS systems, climate change science or related fields. Attendance at the school is primarily by US and Canadian students however a number of international students have attended over the course of the programme. The RECS school students all come via recommendation with targeted recruiting and limited advertising.

The US-Norway Summer School on Carbon Capture, Transport & Storage

The US-Norway summer school started in 2004 as an initiative under the US-Norway Bilateral Agreement on Energy Technology Collaboration between the US Department of Energy and the Norwegian Ministry of Petroleum and Energy. Like the RECS school the US-Norway summer school is organised by EnTech Strategies in collaboration with Los Alamos National Laboratory, Sintef, NTNU, and Polytek. The first event was held in the U.S. and the second two in Norway. Attendance at the school is made up of ten students and early career professionals from each country. This school also covers all aspects of CCS and runs for six days which include

lectures, group work and a field trip to a CCS relevant destination. Combined the US-Norway Summer School and the RECS summer school have had a total combined attendance of one hundred and seventy-five students and young professionals over the course of the two programmes.

UK-Italy International School on CCS

The UK-Italy International School on CCS was held in Sicily in 2007 and was organised by the British Embassy, together with the Italian Ministry of Economic Development. The school involved around one hundred students, teachers and high level experts from around the world who were brought together to discuss and exchanging views on the most challenging issues relating to the use of clean coal and CCS. The event lasted for seven days and covered capture, storage and the role of CCS in Energy Policy and Climate Change Control from a European perspective. Unlike the three summer schools mentioned thus far, the UK-Italy school required the attendees to pay to attend. This summer school was also a one off event rather than the annual series mentioned above.

CO2GeoNet

CO2GeoNet is the European Network of Excellence on geological storage of CO_2 and is sponsored by the European Commission. CO2GeoNet is an ongoing programme that comprises more than one hundred and fifty researchers and postgraduate students who are working towards efficient and safe CCS as a solution for clean and dimate-friendly energy production and consumption. This programme covers all aspects of CCS and includes training for undergraduate and Masters university students. In the future CO2GeoNet is also looking to develop a PhD programme to be integrated with the ongoing joint research activities and research outputs.

In addition to the five larger scale CCS programmes mentioned above there are also some smaller scale initiatives and broader capacity building efforts that do involve students. One example of the more focused initiative is the CO_2ReMoVe CCS monitoring and verification course. CO_2ReMoVe, like CO2GeoNet is a project funded by the European Union which looks to develop technology and contribute to regulatory development in the area of monitoring and verification of CCS. The course aims to provide an introduction and overview to CCS, monitoring and verification. The training course is aimed at Masters and PhD students, over a 2-day period. The content and material of the course will be provided by members of the CO2ReMoVe project team. The course will be presented as a series of lectures and is structured so it can be used several times by different people if required. Furthermore will the course be available on the CO2ReMoVe website.

There are also a number of capacity building initiatives that are ongoing. One in particular is the CSLF series of capacity building workshops that held its third event in Saudi Arabia this year. Although this series is not specifically aimed at students it does provide an opportunity for a small number of students in developing countries to interact with their peers and with experts in the field of CCS.

4. Conclusion and Future Work

Through the combination of getting feedback from students currently studying in the field of CCS and by looking at the current school and courses available to CCS students a number of conclusions can be drawn.

Firstly we think it can be seen from both the questionnaire responses and the current CCS education programmes that in developed countries there is a lot of opportunity for students who are studying CCS to interact with other students and industry, attend conferences and present their work. However the issue is that currently there is no formal way of introducing students to the CCS field but rather it relies on a select number of universities and interested staff to pick up the students as they graduate and introduce them to the concept of CCS. The concern is that not enough students are being introduced through the current system to the concept of CCS early enough in their education (prior to post graduate studies). Without this early introduction to CCS, it may mean that the industry as a whole will not get the throughput of students that will be required to meet the demands of the industry as they try to satisfy the required significant need for CCS in the future.

The other important issue that has been highlighted is the differing opportunities for students in developing countries to interact with industry but more importantly other students. There was a significant difference in the results

between the student-student interactions in developed countries compared to developing countries. Student-student interaction is of great importance as it allows students to increase their network of peers and allows them to maintain an overarching perspective of how their work relates to others and to the CCS industry as a whole. It is generally understood that if CCS is to make the significant impact of global emissions that is required a lot of the application of CCS will be in developing countries such as China, India, South Africa, Brazil and others. This means educational capacity development and in particular improved student-student interaction in these regions will be particularly important and needs to be addressed.

There are a number of potential options that could help address the issues highlighted above. Firstly, organisations could look to run programmes for undergraduate students similar to those currently running for post-graduate students. This process would begin to introduce students to the concepts relating to CCS earlier in the educational career which could help stimulate more interest in the subject and get more students looking to move into this field after graduating. The major concern with this programme would be the amount of work required to hold each school and the limited number of students you could have attend such a school each year.

A second option could bet to run the programme but for professors and lectures rather than for undergraduate students. Lecturers from relevant fields such as those highlighted in the questionnaire (Engineering, environmental science, chemistry, geology, political science) could be invited to attend the events with the lecturers then encouraged to incorporate an introduction to CCS in their undergraduate curriculum. This would then have a large multiplying effect in the number of undergraduate students introduced to CCS. Along similar lines, the CCS industry could become more proactive in their engagement with undergraduate studies with experts from CCS volunteering to give guest lecturers in undergraduate courses. These processes could hopefully evolve into a more significant allowance of CCS discussion being factored into relevant courses in the future as the commercial activities in the industry also ramp up

5. Acknowledgements

Funding for the work described in this paper was provided by the IEA Greenhouse Gas R&D Programme. The views expressed are those of the authors and do not represent those of the IEA, the IEA Greenhouse Gas R&D Programme or its members.